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# Integrating Beyond Capability Maturity Models®

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**Abstract.** The Federal Aviation Administration (FAA) has been successfully pursuing integrated process improvement since 1997 using FAA's integrated Capability Maturity Model® (FAA-iCMM®). FAA-iCMM v1.0 integrated three CMMs: the software, systems engineering, and software acquisition models. Version 2.0 additionally integrates several important improvement approaches including ISO 9001:2000, EIA/IS 731, Malcolm Baldrige National Quality Award, CMMI, ISO/IEC TR 15504, ISO/IEC CD 15288, and ISO/IEC 12207. By integrating beyond CMMs, the FAA-iCMM now contains guidance for improving business and technical processes ranging from enterprise management to operation and disposal.

This paper describes FAA-iCMM v2.0, points out specific contributions from new sources, and illustrates some insights gained from taking a broader perspective - when integrating *beyond* CMMs. The paper will be of interest to any organization that has been using multiple standards and finds that approach too expensive, confusing, or ineffective. It will also be of interest to organizations that do business with the FAA.

## INTRODUCTION

There are a variety of improvement models, standards, and documents available that might help an organization improve parts of its business. But can these improvement approaches, when individually applied, help the overall enterprise improve in an effective and efficient way? Is it possible to integrate these various approaches into a single model?

The FAA has found that using an improvement approach that integrates CMMs has been an effective path to improvement across a large, diverse, and complex enterprise (see Ibrahim 2000). However, integrating CMMs is not enough since there are many important processes not considered in CMMs today. Building on successes in integrated process improvement using the FAA-iCMM (or iCMM) v1.0, the FAA has now included a host of other standards and models, beyond CMMs, in v2.0 of the iCMM. This paper describes that new model, and some of the insights gained by integrating beyond CMMs.

The paper is organized as follows.

- Background
- Development of Version 2.0
- Overview of Version 2.0
- Beyond CMMs - What did the additional standards, models, and documents bring?
- Next Steps
- Summary and Conclusions

## BACKGROUND

The FAA developed the iCMM v1.0 (FAA-iCMM 1997) to guide improvement of its engineering, management, and acquisition processes in an integrated, effective, and efficient way. That initial version of the model integrated the CMMs for software (SW-CMM 1993), systems engineering (SE-CMM 1995), and software acquisition (SA-CMM 1996). Since 1997, version 1 of the iCMM has been successfully deployed across many parts of the FAA. Benefits realized and lessons learned in using iCMM v1.0 are described in (Ibrahim 2000).

## DEVELOPMENT OF VERSION 2.0

Based on experiences using iCMM version 1.0, stakeholders proposed changes and enhancements to the model, and in the summer of 2000 it was agreed that the iCMM should be updated. Requirements for the new version were to incorporate lessons learned from the use of version 1.0, to retain currency with evolving models and standards, to extend improvement guidance across additional business and technical activities, and to integrate additional improvement approaches. The expected benefits for the enhanced model included using the single proven framework to improve processes performed across more areas of the enterprise, as had been shown to be an efficient effective approach using the first version of the model.

Eight main source models, standards and documents were selected for integration: ISO 9001:2000 (ISO 2000a), EIA/IS 731 (EIA 1998), Malcolm Baldrige National Quality Award (MBNQA 2000) and

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President's Quality Award (PQA 2000), CMMI-SE/SW/IPPD (CMMI 2000a) and CMMI-A (CMMI 2000b), ISO/IEC TR 15504 (ISO 1998), ISO/IEC 12207 (ISO 1995), ISO/IEC CD 15288 (ISO 2001), and of course iCMM v1.0 which had already integrated 3 CMMs.

As with the development of version 1.0, a high-level mapping table across the major source documents was prepared to demonstrate feasibility. The FAA formed a Configuration Control Board to control the evolution of the iCMM and associated work products, and by November 2000 a team of FAA and external model builders and subject matter experts was formed to develop the next version of the iCMM.

The model was developed and released for extensive internal and external review using a phased approach. Review package one was released in January 2001, containing 12 selected process area descriptions. Reviewer comments were evaluated and incorporated, as appropriate, in review package two, which contained all proposed process area descriptions and was released in March 2001. The last review package had information on staging, capability levels, and generic attributes and was released in May 2001. A workshop was held with selected key external reviewers in late May 2001, reviewing all aspects of the model. Finally, complete coverage mappings of the source models, at the practice level, were developed to assure robustness, compliance, and detailed traceability (Ibrahim et al, 2001).

Approximately 800 internal and external reviewer comments on these packages were received, evaluated, and dispositioned by the author team, and included in the model, as appropriate. The model was then presented to the Configuration Control Board in July 2001 for another review cycle resulting in the approval and publication of version 2.0 of the FAA-iCMM in September 2001. (FAA-iCMM 2001)

## OVERVIEW OF VERSION 2.0

**Scope.** The scope of the model has broadened to include more of the business and life cycle processes performed across an enterprise. Version 2.0 provides best practice guidance on processes used by an enterprise or organization that engages in the acquisition, supply, engineering, development, operation, evolution, support, and management of products and services. It integrates software engineering, systems engineering, acquisition, and integrated process and product development disciplines, and includes leadership and strategic processes to assure alignment of projects and activities with enterprise vision, mission, goals, and objectives. It covers the complete product or service life cycle.

iCMM v2.0 provides best practice guidance for use in improving these processes and in measuring their capability, value, and effectiveness.

**Structure.** The iCMM continues to follow the "continuous with staging" architecture and representation that was used in the iCMM v1.0. This single representation provides a path for improving both process capability and organizational maturity and it has been validated as an effective structure for supporting organizations in achieving their business goals.

**Process Areas.** The process dimension focuses on process performance and provides guidance specific to processes performed across an enterprise. It includes 23 process areas, just as did iCMM version 1.0, but there are major changes.

Three process areas are new to the iCMM: Integrated Enterprise Management, Operation and Support, and Information Management. One process area (Transition) was extended to become Deployment, Transition, and Disposal. Three process areas from version 1.0 were integrated into other process areas: Prevention became part of Quality Assurance and Management, Peer Review is included in Evaluation, and Product Evolution is covered in Integrated Enterprise Management, and Innovation.

Another innovation is that both Process Definition and Process Improvement process areas are no longer restricted to defining and improving organizational processes. The new process areas are applicable to any level of improvement.

There are now three categories: Management, Life Cycle, and Support processes. The five *management* processes initiate, align, plan, track, and control activities that will accomplish the objectives of the enterprise, organization, project, or team. They oversee the execution of the other processes in the model. The eight *life cycle* processes are used to develop, maintain, transition, and operate a product or service in order to provide and sustain the services that a customer or stakeholder needs. These processes cover the typical life cycle of a product or service, including disposal. The ten *support* processes are used by other process areas when needed, and contribute to the success, quality, and continuous improvement of all the processes.

All process areas contain goals and essential base practices that contribute to goal achievement. However, a new feature in version 2 is that base practices also may be augmented with "Additional

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Practice Guidance". These are additional practices that relate to the base practice characteristic, but that may go beyond what is considered basic or essential. They are not used for appraisal purposes, but are included to provide more process improvement guidance.

The 23 process areas of the iCMM v2.0, with their categories, and benchmarking maturity level stagings (when applicable), are shown in Table 1.

| *Category* | *FAA-iCMM Version 2.0 Process Area* |
|---|---|
| Manage-ment | Integrated Enterprise Management *(ML 3)* |
| | Project Management *(ML 2)* |
| | Supplier Agreement Management *(ML 2)* |
| | Risk Management *(ML 3)* |
| | Integrated Teaming *(ML 3)* |
| Life Cycle | Needs *(ML 3)* |
| | Requirements *(ML 2)* |
| | Design *(ML 3)* |
| | Design Implementation *(ML 3)* |
| | Integration *(ML 3)* |
| | Evaluation *(ML 2)* |
| | Deployment, Transition, & Disposal*(ML 2)* |
| | Operation and Support *(not staged)* |
| Support | Alternatives Analysis *(ML 3)* |
| | Outsourcing *(ML 2)* |
| | Quality Assurance & Management *(ML 2)* |
| | Configuration Management *(ML 2)* |
| | Information Management *(not staged)* |
| | Measurement and Analysis *(ML 2)* |
| | Process Definition *(ML 3)* |
| | Process Improvement *(ML 3)* |
| | Training *(ML 3)* |
| | Innovation *(ML 5)* |

**Table 1: Process Areas, Categories, and Maturity Level (ML) Stagings**

**Capability Levels.** The capability dimension focuses on process improvement and provides guidance for managing and improving any process. It includes six levels of process capability, with generic practices staged at the various levels. Major changes include more clearly tying process performance objectives to business objectives, and planning and tracking those measurable performance objectives at capability level 2. Level 2 improvements include corrective action for the performed process. At capability level 3, process improvement extends to improving both the organizational process, and the defined processes used on the projects. These improvements may be based on results from using statistical process control techniques at capability levels 4 or 5, or they may be based on any improvement techniques the organization uses at capability levels 2 and 3. Table 2 lists the generic practices and their capability levels.

**Staging.** Process areas are grouped or staged into maturity levels for benchmarking purposes and to provide guidance regarding what areas to focus on together or next. The process area staging described in Table 1 is designed for benchmarking with existing CMMs. Two process areas are not staged in that table since their content has not yet been included in any CMM benchmarks. Note that alternative stagings are also available with version 2 to provide guidance in various organizational contexts. Following maturity level definitions in CMMI, levels 4 and 5 require all process areas staged through those levels to have satisfied capability levels 1, 2, and 3. Then processes are selected, based on the business objectives of the organization, to be placed under statistical process control at levels 4 and 5.

| *Capability Level* | *FAA-iCMM Version 2.0 Generic Practice* |
|---|---|
| Level 0 | This is an incomplete process and there are no generic practices at this level. |
| Level 1 | Identify work scope |
| | Perform the process |
| Level 2 | Establish organizational policy |
| | Document the process |
| | Plan the process |
| | Provide adequate resources |
| | Assign responsibility |
| | Ensure skill and knowledge |
| | Establish work product requirements |
| | Consistently use and manage the process |
| | Manage work products |
| | Objectively assess process compliance |
| | Objectively verify work products |
| | Measure process performance |
| | Review performance with higher-level management |
| | Take corrective action |
| | Coordinate with participants and stakeholders |
| Level 3 | Standardize the process |
| | Establish and use a defined process |
| | Improve processes |
| Level 4 | Stabilize process performance |
| Level 5 | Pursue process optimization |

**Table 2: Generic Practices**

**Appraisal and Generic Attributes.** The FAA-iCMM Appraisal Method (FAM) (Ibrahim et. al. 1999) already integrates a variety of approaches for appraising against the integrated model, offering six methods and

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variations. With version 2.0 of the iCMM, however, the FAM is being enhanced to include a new appraisal variation that provides improved objectivity in measuring generic attributes. Generic attributes have been introduced into the iCMM v2.0 as a way of measuring the *usefulness* and *cost effectiveness* of process performance results. For more information on generic attributes, see (Wells et al. 2002).

## BEYOND CMMS

Integrating a variety of improvement approaches into the structure of the iCMM brought many challenges. Each approach however contributed significantly to the content, strength, comprehensiveness, usefulness, and clarity of the model. Since many of the same topics were covered, but in different ways, these various perspectives built upon each other and helped to develop cohesive coverage of model content. As a result of integrating these various perspectives, it is expected that using the single integrated model will help in achieving improvements based on the guidance of all the sources. Furthermore, it is a mechanism for aligning an enterprise in a common improvement effort.

This section highlights a few of the decisions and contributions made as a result of integrating the major new sources. Each iCMM version 2 practice has a long story behind it, but … only a brief summary is provided here. The interested reader can gain a more comprehensive understanding of this topic by examining *Mapping Table Supplement to the FAA-iCMM v2.0*, which maps each of these sources to the iCMM v2.0 at the practice level (Ibrahim et al. 2001). A high-level summary of the contents of these sources is also available in *iCMM v2.0 – Frequently Asked Questions* (see Ibrahim 2001).

Note that all content in these source documents is integrated into the iCMM except for some items pertaining to human resource management (e.g., organizational recruitment, employee performance evaluation and management, staff records, and staff retention). These items were identified as beyond the scope of version 2.0. (see Next Steps).

**ISO 9001:2000 Quality Management Systems.** ISO 9001 focuses on quality, as the fulfillment of requirements. The standard is intended for use where an organization needs to demonstrate ability to provide products that meet requirements, and aims to enhance customer satisfaction. In that sense it is a "supplier's model". It is generic and intended to be applicable to all organizations. Its 5 major clauses and 23 subclauses are concisely described in 14 pages.

Many of the general ISO 9001 requirements are included in iCMM generic practices, especially when applied to Quality Assurance and Management process area. However, new requirements in ISO 9001:2000 influenced the iCMM in several ways: to include prevention as a natural part of quality assurance (at ML2), to specifically require the determination and monitoring of customer satisfaction (in the Needs process area of the iCMM), and as a strong reinforcement for the increased emphasis on measurement that is found throughout iCMM v2. ISO 9001, by including continual improvement as one of its clauses, also influenced the decision to include a generic practice at capability level 3 that specifically requires improvement of both organizational and defined processes (no need to wait to level 5!) (also, measurement using statistical process control can be done at any level). The iCMM Process Improvement process area is also, consistently, staged at maturity level 3 (instead of ML5). Lastly, to assure alignment and clarity regarding ISO 9001, the iCMM v2 has included a base practice in Quality Assurance and Management that requires "establishing and maintaining a quality management system". This is an example of what we call "controlled redundancy" in the iCMM since quality management system requirements are already covered in generic practices when applied to Quality Assurance and Management. This new base practice raises the bar for achieving capability level 1 in Quality Assurance and Management, since a quality management system must have a documented process, policy, and quality assurance on the process. For other process areas, these requirements are attached to capability level 2.

In all areas, the iCMM provides much more detailed guidance on what might be done to satisfy ISO 9001 requirements, pointing out the advantages to be gained by using the integrated model rather than ISO 9001 as a separate standard.

Lastly, guidance found in ISO 9004:2000 (ISO 2000b) supported the formulation of iCMM generic attributes.

**Malcolm Baldrige National Quality Award and President's Quality Award Criteria**. These criteria are very similar and thus were considered as a single source. The criteria focus on overall organizational performance excellence and business results, and are structured into seven categories, and 19 main items within those categories. These criteria had a major influence on the iCMM in several areas. The Leadership and Strategic Planning categories brought true enterprise-wide performance management concepts into the iCMM, including visioning, organizational alignment, strategic direction, and identification of key performance measures and indicators. These MBNQA/PQA criteria contributed significantly to the

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new Integrated Enterprise Management process area. The Customer Focus category brought a new marketing flavor to the Needs process area. The Business Results category reinforces the use of measurement in a variety of performance areas including supplier and partnering processes.

In return, the iCMM provides much more detailed guidance to support the MBNQA/PQA Process Management category, and those items that require keeping methods and processes current with business needs and directions, especially via the greatly enhanced Process Improvement process area.

**EIA/IS 731.** EIA/IS 731 is an interim standard that supports the development and improvement of systems engineering capability. It integrates 2 systems engineering models (SE-CMM (a source of iCMM v1.0) and the Systems Engineering Capability Assessment Model (SECAM)) and it contains a wealth of systems engineering knowledge. By including all practices from its 19 Focus Areas and 6 capability levels, the iCMM carries forth that knowledge.

EIA/IS 731 contains over 400 practices. Practices are simply listed, organized to support different themes within the focus areas. One reason for including the "Additional Practice Guidance" feature of iCMM v2.0 (described above) was to assure the capture and coverage of EIA/IS 731 practices.

An important new concept in the iCMM is that of generic attributes, as described above, and this feature is based to a large extent on generic attribute principles put forth in EIA/IS 731.

**ISO/IEC TR 15504.** ISO/IEC 15504 has always had a major impact on the iCMM, strongly influencing the original adoption of the continuous structure of the model in version 1.0, and as continued in version 2. The iCMM is compatible with the reference model as described in ISO/IEC TR 15504 Part 2. But the impact of 15504 goes beyond the model and its practices. FAA's process improvement approach is fashioned after 15504 Part 7: Guide for Use in Process Improvement, and the iCMM Appraisal Method was formulated to be conformant with requirements for assessments as described in ISO/IEC TR 15504 Part 3. 15504 Part 6 has provided inputs to FAA's guidelines for authorizing lead appraisers. Lastly, effectiveness measures described in ISO/IEC TR 15504 Part 7 have influenced the iCMM rendition of generic attributes.

**Acquisition and Supply.** Both acquisition and supply processes are explicitly called out in three of the ISO sources used in developing version 2: ISO/IEC CD 15288, ISO/IEC TR 15504, and ISO/IEC 12207. Processes, practices, activities, and tasks in these areas helped clarify how the iCMM version 2 provides guidance for both the acquisition and supply activities that an enterprise carries out. The FAA-iCMM is applicable for organizations that develop or provide (supply) products or services, and for those internal or external customers (acquirers) whose needs must be met. It similarly focuses on assuring agreement in these two-party situations.

**Full life cycle coverage.** Two of the source documents are specifically intended to establish common frameworks for the life cycle (for software in ISO/IEC 12207, of systems in ISO/IEC CD 15288). The iCMM needed to cover the complete life cycle of products and services, and these life cycle standards contributed to new process areas in version 2, especially in the areas of deployment, transition, disposal, operation, and operational support.

**ISO/IEC CD 15288.** Although this document was still in committee draft, its Enterprise Processes brought additional insights that were included in the iCMM in the Integrated Enterprise Management process area. The Investment Management Process was particularly helpful, and nicely complemented the ideas put forth in the Malcolm Baldrige criteria. ISO/IEC CD 15288 also supported the iCMM project team decision to include a new process area for Information Management. Lastly, ISO/IEC CD 15288 contributed to the strengthening of the Needs and Requirements process areas of the iCMM, in particular through its focus on human factors, safety, security, and performance measures.

**CMMI.** iCMM source documents included those developed by the Capability Maturity Model Integration[sm] (CMMI[sm]) project. CMMI-SE/SW/IPPD brought updates to the SW-CMM into the iCMM, since one of the CMMI sources was SW-CMM v2.0 draft C, and all of CMMI was included in the iCMM. Of course, the iCMM directly integrated all of EIA/IS 731 (not via CMMI). IPPD concepts introduced in the iCMM v2 came both from the IPPD extensions to CMMI as well as from the IPD-CMM directly.

A major contribution from CMMI was the staging of Measurement and Analysis at ML2. Since iCMM benchmark staging is intended to be at least equivalent to staging levels defined by CMMI (and the SA-CMM), that CMMI staging change is reflected in the iCMM. Similarly, the definitions of maturity levels 4 and 5 in the FAA-iCMM follow the CMMI definitions.

The draft CMMI extension including acquisition (CMMI-SE/SW/A) was additionally mapped to the iCMM, but no new iCMM practices resulted from that endeavor.

**iCMM v1.0, Acquisition, and Human Factors.** From

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the very beginning, the iCMM has integrated acquisition concepts throughout the model, based on the initial decision to include the Software Acquisition CMM (SA-CMM 1996) in iCMM version 1.0. The SA-CMM continues to influence the iCMM in terms of staging decisions (e.g. ML2 on the iCMM must be at least equivalent to ML2 on the SA-CMM), and the practices included (iCMM v2.0 includes updated practices from SA-CMM v1.02 (SA-CMM 1999)).

Lastly, the Human Factors Engineering Addendum to the iCMM v1.0 (HFE 1999) was integrated into version 2 of the iCMM.

## NEXT STEPS

**The Vision.** The vision is to provide a standard, single reference model to guide enterprise-wide improvement. The general strategy to achieve the vision is to evolve the iCMM through a series of phases, each addressing broader needs, and to evolve sponsorship across broader participating organizations.

That strategy is being realized. Best practice guidance from other widely used and recognized models and standards adopted by government and industry has now been integrated into the iCMM v2.0. There are other areas for enhancement that are being considered, and further improvements to make in areas such as safety, security, human resource management, and financial management. Sources may include other CMMs (such as SSE-CMM and P-CMM) and other sources beyond CMMs.

**Safety and Security.** Next areas being pursued are security and safety. This effort is being carried out collaboratively with FAA and the US Department of Defense as joint sponsors. The results are intended for use with both the iCMM and CMMI.

**Transitioning to iCMM Version 2.** Guidelines have been prepared to help programs and organizations transition to the new model. These supporting documents also point out ways that using the single model can help pursue multiple achievement goals concurrently. Transition guidelines and frequently asked questions capture rationale for changes made (see (Ibrahim 2001) and (Ibrahim 2002).

**Validating the Model.** Version 2 of the iCMM is being validated in practice and through appraisal, just as version 1.0 was. There are many questions to explore such as: Does a general CMM-type framework work as a mechanism to implement the requirements of different standards? Do levels 4 and 5 really need to be isolated when measurement is always important in process improvement, and statistical process control can be applied at any time? We anticipate continuous learning and continuous improvement based on experiences of iCMM stakeholders.

**Using the Model Outside FAA.** The iCMM is not specific to the FAA. It can benefit any organization that seeks single-model guidance for performance excellence at the enterprise, project, and process level, in a variety of disciplines, and for all life cycle phases.

Some external organizations have been applying the iCMM as an available and validated solution to the integration problem. The FAA offers public courses periodically, and external lead appraisers are typically included on FAA appraisal teams so that they can gain and bring back to their organizations experience with the iCMM and its application.

**FAA Suppliers.** The FAA is encouraging its suppliers to improve their processes, along with the FAA, as part of its source selection and contract monitoring processes. Plans are underway to appraise supplier process capability using the iCMM v2.0 in a post award setting in order to mitigate risks in areas identified as critical to project success. Suppliers would be expected to address significant weaknesses uncovered during the appraisal.

## SUMMARY AND CONCLUSIONS

FAA enhanced the iCMM to include process improvement guidance from the most widely recognized improvement approaches, extending beyond traditional CMMs. Each source brought insights resulting in a comprehensive, integrated improvement model. iCMM version 2.0 includes both business and technical process enhancements integrating enterprise-level goal setting and business results processes together with the technical processes to accomplish those goals. This is a means to seek overall enterprise excellence.

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**BIOGRAPHY**

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Linda has been working in software engineering for over 30 years, as practitioner, educator, and researcher; in the US, Europe, and Middle East. She worked at the Software Engineering Institute for several years, and is a member of the CMMI Steering Group.

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